

## Sensory Descriptive Analysis and Physicochemical Properties of *Spirulina platensis* from Different Drying Processes: Hot Air Drying and Microwave Vacuum Drying

Ittikorn Kuatrakul<sup>1</sup>, Parpajit Kuarthongsri<sup>1</sup>, Chananya Yabuuchi<sup>1</sup>,  
Krongjit Somsai<sup>1</sup> and Niramom Utama-ang<sup>2\*</sup>

<sup>1</sup>Division of Product Development Technology, Faculty of Agro-Industry,  
Chiang Mai University, Chiang Mai, Thailand

<sup>2</sup>Lanna Rice Research Center, Chiang Mai University, Chiang Mai, Thailand

### Abstract

This research compared the sensory and physicochemical characteristics of dried *Spirulina* (*Spirulina platensis*) using hot air drying (50°C, 8 h) versus microwave vacuum drying (4800 watts, 40 min). Ten trained panelists received three months of training in terminology development, reference selection, intensity scaling (15 centimeter line scale) and warm up sample before conducting generic descriptive analysis. The sensory descriptive results identified 16 attributes of dried *Spirulina*: green-yellow color, particle size, four odors (fish, salty, seaweed, green), three tastes (salt, bitter, umami), three flavors (chicken, fish, algae) and four aftertastes (oily, bitter, pork, astringent). The method of drying (hot air versus microwave vacuum drying) affected the moisture content, color value (L\*, a\* and b\*), total antioxidant activity, total phenolic compounds, color attribute, fishy odor, and seaweed odor of dried *Spirulina* with significant difference ( $p \leq 0.05$ ). Microwave vacuum drying provided better color and aroma than the hot air drying ( $p \leq 0.05$ ). The intensities of green-yellow color, fishy odor, and seaweed odor of *Spirulina* from hot air drying were  $8.32 \pm 0.93$ ,  $5.83 \pm 0.77$  and  $8.10 \pm 0.51$ , respectively. Those from microwave drying were  $5.27 \pm 0.80$ ,  $6.97 \pm 0.52$ , and  $6.58 \pm 0.82$ , respectively. However, the taste, flavor and aftertaste of both dried *Spirulina*s did not differ significantly ( $p \geq 0.05$ ). Nevertheless, the lower of total antioxidant activity and total phenolic compounds loss of dried *Spirulina* samples were found in sample from microwave vacuum drying. The two different drying methods used affected the physicochemical and sensory characteristics of dried *Spirulina*.

**Keywords:** *Spirulina platensis*, descriptive analysis, hot air drying, microwave vacuum drying

### 1. Introduction

*Spirulina platensis* is a blue-green Cyanobacterium, owing to the presence of both chlorophyll (green) and phycocyanin (blue) pigments in its cellular structure [1]. Spirulinacan live in either fresh or saltwater. It is produced commercially worldwide, and the dry product is a valuable food supplement. *Spirulina* is rich in protein (60-70% by dry weight), vitamins and minerals; contains many essential amino acids and fatty acids [2]; and is an expensive source of pigment for the cosmetics industry [3]. *Spirulina* was used as a nutritional supplement for humans and animals, and

---

\*Corresponding author: E-mail: niramom.u@cmu.ac.th

as well as source of active metabolite in the pharmaceutical [4]. In vitro and in vivo studies have shown that Spirulina can effectively treat cancer and allergies, viral and cardiovascular diseases, hepatotoxicity, hyperglycaemia, and inflammation [5]. The polyunsaturated fatty acids and pigments in Spirulina have antioxidant properties [6].

The objective of drying foods is the remove of water from solids, helping to minimize microbial growth and chemical deterioration; this is an important option in food manufacturing [7]. Many drying methods, including oven drying, freeze-drying, and microwave drying, have been used to preserve Spirulina. Previous research has shown that spray and convective drying of Spirulina reduces its antioxidant capacity by one-half [8]. This microwave vacuum drying method has benefits of microwave vacuum drying Spirulina; however, to date, the studies have mainly focused on the effect of drying method on the phenolic content and antioxidant capacity, rather than the sensory characteristics of Spirulina.

Many sensory programs have been developed specifically for QC/QA purposes [9]. Sensory evaluation is the only method that provides integrated, direct measurements of perceived intensities of target sensory attributes of products. Key or target attributes should relate to consumer acceptance and purchase behavior [10]. This research compared the effects of hot air versus microwave vacuum drying of Spirulina (*Spirulina platensis*) on the dried product in terms of total antioxidant activity, total phenolic compounds and sensory characteristics.

## **2. Materials and Methods**

### **2.1 Fresh Spirulina sample**

The fresh Spirulina (*Spirulina platensis*) sample was harvested from the Green Diamond Co., Ltd. (Chiang Mai, Thailand), located in northern Thailand. The fresh Spirulina was stored in aluminum foil bags at 4°C until used in the experiment. The fresh Spirulina was analyzed for moisture content, crude protein, crude fat, crude fiber, ash, total antioxidant activity and total phenolic compounds.

### **2.2 Biomass Drying**

Spirulina sample was dried using two different methods: hot air and microwave vacuum drying. For hot air drying, the dryer was set at 50 °C and the samples were dried approximately 8 hours or until their moisture content were lower than 0.10 kg kg<sup>-1</sup> (wet basis) [2]. The microwave vacuum drier was set at 4800 watt for 40 min. The thickness of sample was 3 mm. The dried samples were ground on a knife mill and sieved (150 mesh), packed in aluminum foil bags and stored in a desiccator at ambient temperature.

### **2.3 Physicochemical analysis**

The color of the *Spirulina* samples was measured using a Minolta colorimeter (CR-410, Konica-Minolta, Japan) in CIE Lab system (L\*,a\* and b\*) calibrated by standard plate of white surface.

Moisture, crude protein (NX 6.25), crude fat and crude fiber content of fresh Spirulina were analyzed by AOAC method [11]. The Spirulina (1g) was extracted with 10 mL of 70% ethanol for 60 min at room temperature and then centrifuge at 6000 rpm at 4°C for 15 min, after which the supernatant was separated from the residue and stored at -4 °C until analysis.

The total antioxidant activity of Spirulina was determined by the DPPH assay according to Brand-Williams *et al.* [12] with some modifications. Each sample of ethanol extract (0.1 mL) was mixed with 3.5 mL of 0.06 mM DPPH (1,1-diphenyl-2-picrihigrazil) ethanol solution, then incubated for 30 min in a dark room at room temperature. The measurements were carried out on a spectrophotometer (UV-vis model 1601, Shimadzu, Japan) at a wavelength of 515 nm. The results were expressed as milligrams of Gallic acid equivalent (GAE) per 100 grams of dry basis.

The total antioxidant activity of *Spirulina* was determined by Ferric reducing antioxidant power according to Sudha *et al.* [13]. The FRAP reagent consisted of 300 mM acetate buffer, 10 mM TPTZ in 40 mM HCL and 20 mM  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  in the ratio of 10:1:1. Freshly prepared and pre-warmed (37°C) of FRAP reagent (1.5 mL) was added in a test tube containing 50  $\mu\text{L}$  of ethanol extracted samples and then incubated at 37°C for 10 min. The absorbance was read against reagent blank (1.5 mL FRAP reagent + 50  $\mu\text{L}$  distilled water) at 593 nm. The results were expressed as milligrams of ferric ions reduced per 100 grams of dry basis.

The total phenolic compounds of *Spirulina* was determined according to Assis *et al.* [14]. A sample of ethanol extract (0.1 mL) was mixed with 1.6 mL of 7.5% sodium carbonate and 2 mL of Folin-Ciocalteu's reagent. The reaction mixture was left for 30 min. in a dark room at room temperature. The absorbance was recorded at 765 nm. The results were expressed as milligrams of Gallic acid equivalent (GAE) per 100 grams of drybasis.

#### 2.4 Descriptive sensory analysis

The test of dried *Spirulina* samples were conducted in an environmentally-controlled sensory laboratory with partitioned booths at Chiang Mai University. Descriptive analysis employed the generic descriptive analysis method. A trained descriptive sensory panel (10 panelists) was recruited from staff and students with sensory experience at the Department of Product Development Technology, Chiang Mai University, Chiang Mai University, Chiang Mai, Thailand. These training sessions, approximately 2 hours each, were conducted over an 8-day period. Panelist evaluated the dried *Spirulina* and listed the sensory attributes and descriptors for their appearance, aroma, taste, flavor, and aftertaste. References of each attribute were generated and consensus by train panelists. Panelists also determined references to use during evaluations to help them evaluate the appearance, aroma, taste, flavor, and aftertaste. Each panelist rated the intensity of each attribute by first evaluating the reference for that particular attribute, and then giving an intensity rating, with each attribute placed adjacent to a 15-cm horizontal line, anchored one-half inch (13 mm) from each end with directional terms (e.g., weak/strong, slightly/very). Each trained panelist rated the attributes of two dried *Spirulina* samples.

#### 2.5 Statistical analysis

Statistical analysis was conducted using SPSS 17.0 (SPSS Inc., IBM Corp., IL, USA) for the analysis of variance (ANOVA) in determining significant differences between drying methods at a confidence level at 95% ( $p \leq 0.05$ ). Variable means were compared using Duncan's multiple range test. For descriptive analysis, independent sample t-test was used to determine significant differences between two dried *Spirulina* samples at a confidence level at 95% ( $p \leq 0.05$ ).

### 3. Results and Discussion

#### 3.1 Physicochemical composition of fresh *Spirulina platensis*

The physicochemical composition of the fresh *Spirulina platensis* in dry basis was moisture content  $81.38 \pm 2.07$  crude protein content  $69.96 \pm 2.00$  crude fat content  $0.65 \pm 0.17$  crude fiber content  $2.18 \pm 0.55$  and ash  $5.27 \pm 0.55$  in percentage. The total antioxidant activity by DPPH assay, total antioxidant activity by FRAP assay and total phenolic compounds were  $69.82 \pm 13.16$  mgGAE  $100\text{g}^{-1}$ ,  $1585.35 \pm 45.96$  mg $\text{FeSO}_4$   $100\text{g}^{-1}$  and  $371.43 \pm 32.57$  mgGAE  $100\text{g}^{-1}$ , respectively. The color values L\*, a\* and b\* of dried *Spirulina* samples were  $23.22 \pm 0.23$ ,  $-1.55 \pm 0.1$  and  $4.22 \pm 0.26$ , respectively. A prior report has shown that *Spirulina platensis* has a high protein concentration (60-70% of dry weight), whose nutritive value is related to the quality of amino acid [15].

### 3.2 Effect of drying method on physicochemical composition

The result showed no significant different ( $p \geq 0.05$ ) between drying methods on the moisture content. The overall color parameters of Spirulina are affected by the drying methods ( $p \leq 0.05$ ). The L\* a\* and b\* values of dried Spirulina from the microwave vacuum drying were higher than the hot air drying (Table 1). Which indicated that dried Spirulina from the hot air drying darker color less yellow and red than the microwave vacuum drying. The color became darker implying that more browning of the product occurred while less yellow color could imply that pigment destruction had occurred [16]. Authors report higher darkening of the sample at higher drying air temperature for long time [4].

**Table 1.** Comparison of the moisture and color values of fresh, hot-air dried, and microwave-vacuum dried Spirulina samples.

Treatment	Moisture	L*	a*	b*
Microwave drying	4.47±0.90 <sup>b</sup>	42.44±0.71 <sup>a</sup>	-2.82±0.07 <sup>b</sup>	7.26±1.04 <sup>a</sup>
Hot air drying	5.01±0.76 <sup>b</sup>	36.20±0.09 <sup>b</sup>	-3.16±0.02 <sup>c</sup>	3.87±0.08 <sup>c</sup>
Fresh	443.53±60.57 <sup>a</sup>	23.22±0.23 <sup>c</sup>	-1.55±0.10 <sup>a</sup>	4.22±0.26 <sup>b</sup>

\*Mean value ± error (n=2). Different superscripts in same column are significantly different ( $p \leq 0.05$ ). L: lightness; a: chromaticity greenness/redness; b: chromaticity blueness/yellowness.

**Table 2.** Total antioxidant activity and total phenolic compounds of fresh Spirulina and dried samples from hot-air and microwave drying

Treatment	Total antioxidant DPPH ASSAY (mgGAE/100 g (DM))	Total antioxidant FRAP ASSAY (mgFeSO4/100g (DM))	Total phenolic compounds (mgGAE/100 g (DM))
Microwave	52.23±0.41 <sup>b</sup>	964.74±31.68 <sup>b</sup>	273.26±16.88 <sup>b</sup>
Hot air	21.00±0.01 <sup>c</sup>	516.64±44.66 <sup>c</sup>	99.76±3.64 <sup>c</sup>
Fresh	69.82±13.16 <sup>a</sup>	1585.35±45.96 <sup>a</sup>	371.43±39.32 <sup>a</sup>

\*Mean value ± standard error (n=2). Different superscripts in same column are significantly different ( $p \leq 0.05$ ).

The total antioxidant capacity and total phenolic compounds values of fresh Spirulina and dried Spirulina using both drying methods are shown in Table 2. The total antioxidant activity and total phenolic compounds values of dried samples and fresh sample differed significantly ( $p \leq 0.05$ ). The Spirulina sample obtain form the microwave vacuum dryer showed the total antioxidant activity and total phenolic compounds content loss smaller than hot air dryer. The losses of total antioxidant capacity and total phenolic compounds during the drying operation with hot air dryer were more than approximately 50% when comparing the microwave dryer. Costa *et al.* [4] reported that the total antioxidant activity is related to the amount of total phenolic compounds present in Spirulina. Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material. The material can absorb microwave energy directly and internally and convert it into heat [16]. Microwave heating led to the destruction of parenchyma cells in orange peel [17] and hot air

drying of orange peel around 50-60°C apparently promote the minor disruption of cell wall polymers [18]. The intense heat generated from the microwaves creates a high vapor pressure and temperature inside plant tissue, resulting in the disruption of plant cell wall polymers. Consequently, antioxidant activity and total phenolic can be released, thus causing more antioxidant and total phenolic extracted.

### 3.3 Sensory descriptive analysis

Table 3 shows the final list of 16 sensory descriptive attributes and their definitions for Spirulina as agreed upon by all panelists: green-yellow color, particle size, four odors (fish, salty, seaweed, green), three tastes (salt, bitter, umami), three flavors (Chicken, fish, algae) and four aftertastes (oily, bitter, pork, astringent). Ten panelists determined the reference for evaluating the sensory attributes. Each panelist rated the attribute intensity of each reference. The mean intensity rating was calculated and used as the attribute intensity rating for that particular reference. References were used to remind panelists of particular sensory descriptors and help them to differentiate between descriptors [19].

**Table 3.** Attribute, definitions and intensity of dried Spirulina sensory characteristics.

Attribute	Definitions	References (Intensity)
<b>Appearance</b>		
<b>Green-yellow</b>	The color intensity of dried Spirulina from yellow to green	Munsell book 7.5 GY 2/4 (7.0)
<b>Particle size</b>	The dimensions of solid particles of dried Spirulina powder	Powdered sugar 5 g (2.1) Fine crystal sugar 3 g (6.4) Large crystal brown sugar 3 g (10.7)
<b>Aroma</b>		
<b>Fish</b>	Aroma associated with dried fish	Fresh <i>Spirulina platensis</i> 0.1 g (1.0) Fresh <i>Spirulina platensis</i> 1.0 g (5.1) Fresh <i>Spirulina platensis</i> 5.0 g (14.0)
<b>Salt</b>	Aroma associated with salt	Dried fish 0.3 g (3.0) Dried fish 1.0 g (7.7) Dried fish 3.0 g (14.0)
<b>Seaweed</b>	Aroma associated with seaweed	Fresh <i>Spirulina platensis</i> 0.1 g (0.5) Fresh <i>Spirulina platensis</i> 1.0 g (4.2) Fresh <i>Spirulina platensis</i> 5.0 g (8.0)
<b>Green</b>	Aroma associated with green vegetables	Dried lettuce 2.0 g (3.0) Dried Chinese broccoli 2.0 g (8.8) Dried spinach 2.0 g (13.5)

**Table 3.** Attribute, definitions and intensity of dried Spirulina sensory characteristics. (cont.)

Attribute	Definitions	References (Intensity)
<b>Flavor</b>		
<b>Chicken</b>	Aroma associated with cooked chicken perceived by smell perceived when the sample is inside the mouth.	Chicken soup 3.0% W/V (4.0) Chicken soup 10.0% W/V (7.6) Chicken soup 15.0% W/V (14.0)
<b>Basic taste</b>		
<b>Salty</b>	A fundamental taste factor associated with sodium chloride solution perceived by the tongue.	0.20% "Sodium solution" (2.5) 0.35% "Sodium solution" (5.0) 0.50% "Sodium solution" (7.5)
<b>Umami</b>	A fundamental taste factor associated with glutamate solution perceived by the tongue.	0.046% "Monosodium glutamate" (1.0) 0.350% "Monosodium glutamate" (7.5)
<b>Bitter</b>	A fundamental taste factor associated with caffeine solution perceived by the tongue.	0.01% "Caffeine solution" (2.0) 0.02% "Caffeine solution" (3.5) 0.035% "Caffeine solution" (5.0)
<b>Fish</b>	Aroma associated with dried fish perceived by smell perceived when the sample is inside the mouth.	Fish soup 3.0% W/V (3.5) Fish soup 10.0% W/V (7.3) Fish soup 15.0% W/V (12.5)
<b>Seaweed</b>	Aroma associated with seaweed perceived by smell perceived when the sample is inside the mouth.	Seaweed soup 0.5% W/V (2.5) Seaweed soup 2.5% W/V (7.6) Seaweed soup 3.5% W/V (14.0)
<b>Pork</b>	Aroma associated with cooked pork perceived by smell in mouth.	Pork soup 5.0% W/V (5.5) Pork soup 10.0% W/V (8.2) Pork soup 15.0% W/V (12.0)
<b>Astringent</b>	The shrinking or puckering of the tongue surface caused by alum after swallowing.	0.03% "Alum solution" (1.5) 0.05% "Alum solution" (2.5) 0.10% "Alum solution" (5.0)

\*Rated on a 15-cm unstructured line scale with anchors at 1.5 and 13.5 cm.

**Table 4.** Intensity rating of dried Spirulina from hot air drying and microwave drying

Attribute	Drying assay	
	Hot air drying	Microwave vacuum drying
<b>Appearance</b>		
Green-yellow	8.32±0.93 <sup>a</sup>	5.27±0.98 <sup>b</sup>
Particulatesize <sup>ns</sup>	3.20±0.33	3.41±0.32
<b>Aroma</b>		
Fish	5.83±0.77 <sup>b</sup>	6.97±0.53 <sup>a</sup>
Salt <sup>ns</sup>	2.28±0.57	2.28±0.39
Seaweed	8.10±0.51 <sup>a</sup>	6.58±0.83 <sup>b</sup>
Green <sup>ns</sup>	6.31±0.72	5.78±0.57
<b>Basic Taste</b>		
Salty <sup>ns</sup>	1.59±0.38	1.37±0.61
Umami <sup>ns</sup>	0.81±0.22	1.00±0.36
Bitter <sup>ns</sup>	1.96±0.38	1.48±0.37
<b>Flavor</b>		
Chicken <sup>ns</sup>	7.55±0.75	6.73±0.81
Fish <sup>ns</sup>	5.79±0.86	5.48±0.71
Seaweed <sup>ns</sup>	8.62±1.02	8.51±0.99
<b>Aftertaste</b>		
Oily <sup>ns</sup>	1.38±0.33	1.07±0.14
Bitter <sup>ns</sup>	1.29±0.36	1.35±0.27
Pork <sup>ns</sup>	6.71±0.64	6.30±0.57
Astringent <sup>ns</sup>	1.62±0.32	1.44±0.48

Mean value ± standard error (n=10). Different superscripts in same row are significantly different ( $p \leq 0.05$ ).

The generic descriptive analysis results (Table 4.) differed significantly for 3 of the 16 attributes ( $p \leq 0.05$ ) used to describe the dried Spirulina samples (Table 3): color attribute, fishy odor, and seaweed odor ( $p \leq 0.05$ ). Spirulina dried with hot air had more seaweed odor than Spirulina dried with microwave vacuum, but Spirulina dried with microwave vacuum had the lightest color and more fish odor than Spirulina dried with hot air. The results are presented in a spider diagram (Figure 1). Green-yellow color, fish aroma, and seaweed aroma were the only dried-Spirulina attributes that differed between the two drying methods.

#### 4. Conclusions

The drying method affected on the color value L\*, a\*, and b\*, total antioxidant activity, total phenolic compounds, color attribute, fishy odor, and seaweed odor of Spirulina samples. Microwave-vacuum drying retained more total antioxidant activity and total phenolic compounds than hot-air drying. Microwave-vacuum drying also produced a lighter color and stronger odor

than hot-air drying. The taste, flavor and aftertaste of both dried *Spirulina* samples did not differ significantly. The two different drying methods affected the physicochemical properties and sensory characteristics of *Spirulina platensis* differently.

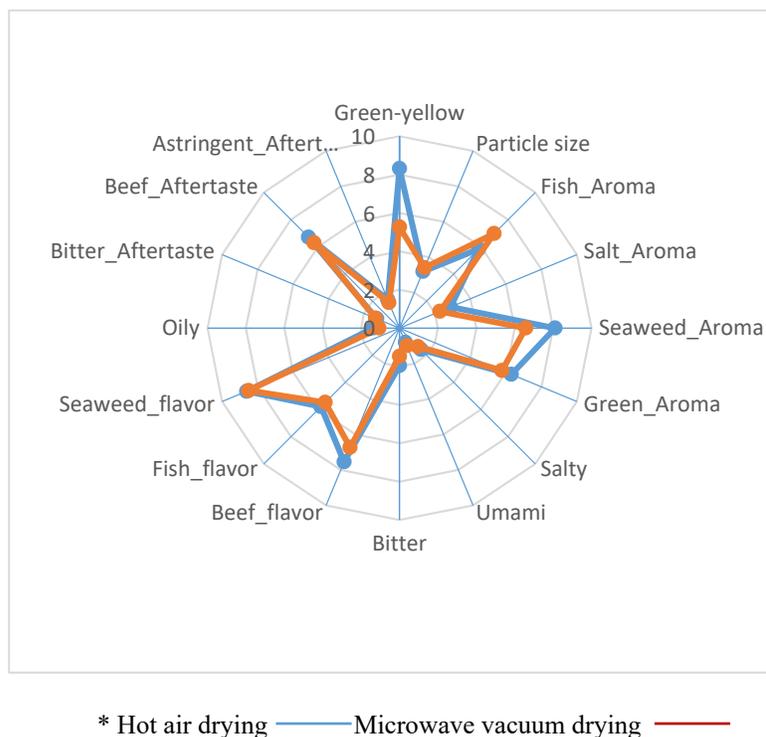


Figure 1. Sensory characteristics of dried *Spirulina platensis*

## 5. Acknowledgment

The authors gratefully acknowledge the Green Diamond Co., Ltd. for providing the *Spirulina* that made this work possible.

## References

- [1] Sivasankari, S., Naganandhini, M.N. and Ravindran, D., 2014. Comparison of different extraction methods for phycocyanin extraction and yield from *Spirulina platensis*. *International Journal of Current Microbiology and Applied Sciences*, 3(8), 904-909.
- [2] Oliveira, E.G., Duarte, J.H., Moraes, K., Crexi, V.T. and Pinto L.A.A., 2010. Optimisation of *Spirulina platensis* convective drying evaluation of phycocyanin loss and lipid oxidation. *International Journal of Food Science and Technology*, 45, 1572-1578.
- [3] Richmond, A., 1998. *Spirulina*. In: M.A. Borowitzka and L.J. Borowitzka. *Micro-Algal Biotechnology*. Cambridge: Cambridge University Press, pp.85-121.

- [4] Costa, B.R., Rocha, S.F., Rodrigues, M.C.K., Pohndorf, R.S., Larrosa, A.P.Q. and Pinto, L.A.A., **2015**. Physicochemical characteristics of the *Spirulina* sp. dried in heat pump and conventional tray dryers. *International Journal of Food Science and Technology*, 50, 2614-2620.
- [5] Kepekci, R.A. and Saygideger., S.D., **2012**. Enhancement of phenolic compound production in *Spirulina platensis* by two-step batch mode cultivation. *Journal of Applied Phycology*, 24, 897-905.
- [6] Estrada, J.E.P., Bescos, P.B. and Fresno, A.M.V., **2001**. Antioxidant activity of different fractions of *Spirulina platensis* protean extract. *IL Farmaco*, 56(5-7), 497-500.
- [7] Krokida, M.K., Karathanos, V.T., Maroulis, Z.B. and Marinos-Kouris., D. **2003**. Drying kinetic of some vegetables. *Journal Food Engineering*, 59(4), 391-403.
- [8] Sarada, R., Pillai, M.G. and Ravishanker, G.A., **1999**. Phycocyanin from *Spirulina* sp: Influence of processing of biomass on phycocyanin yield, analysis of efficacy of extraction methods and stability studies on phycocyanin. *Process Biochemistry*, 34(8), 795-801.
- [9] Lawless, H.T., **1995**. Dimensions of quality: a critique. *Food Quality and Preferences*, 6(3), 191-196.
- [10] Bleibaum, R.N., Stone, H., Tan, T., Labreche, S., Saint-Martin, E. and Isz, S. **2002**. Comparison of sensory and consumer results with electronic nose and tongue sensors for apple juices. *Food Quality and Preference*, 13 (6), 409-422.
- [11] AOAC, **2000**. Official Method of Analysis of AOAC International. 17<sup>th</sup> ed. The Association of Official Analytical Chemists. Arlington, Virginia.
- [12] Brand-Williams, W., Cuvelier, M.E. and Berset, C., **1995**. Use of free radical method to evaluate antioxidant activity. *LWT-FOOD Science and Technology*, 8, 25-30.
- [13] Sudha, S.S., Karthic, R., Rengaramanujam, J. and Athulya, M., **2011**. Antimicrobial activity of *Spirulina platensis* and *Aphanothrexe* sp. on selected clinical bacterial isolates and its antioxidant activity. *South Indian Journal of Biological Sciences*, 1(2), 87-98.
- [14] Assis, L.M., Machado, A.R., Motta, A.S., Casta, J.A.V. and Souza-Soares, L.A., **2014**. Development and characterization of nanovesicles containing phenolic compounds of microalgae *Spirulina strain* LEB-18 and *Charella pyenoidosa*. *Advance in Materials Physics and Chemistry*, 4, 6-12.
- [15] Koru, E., **2012**. Earth Food *Spirulina (Arthrospira)*: Production and quality standarts, food additive, In: Yehia El-Samragy (ed), ISBN: 978-93-510067-6, [Online] Available at: <http://www.intechopen.com/books/food-additive/earth-food-Spirulina-arthrospira-production-and-quality-standards>.
- [16] Inchuen, S., Narkrugs, W. and Pornchaloempong, P., **2010**. Effect of drying method on chemical composition, color and antioxidant properties of Thai Red Curry powder. *Kasetsart Journal (Natural Science)*, 44, 142-151.
- [17] Kratchanova, M., Pavlova, E. and Panchev, I., **2003**. The effect of microwave heating of fresh orange peels on the tissue and quality of extracted pectin. *Carbohydrate Polymers*, 56, 181-185.
- [18] Garau, M.C., Simal, S., Rosselloo, C. and Femenia, A., **2007**. Effect of air-drying temperature on physico-chemical properties of dietary fibre and antioxidant capacity of orange (*Citrus aurantium* v. *Canoneta*) by-products. *Food Chemistry*, 104(3), 1014-1024.
- [19] Phillipa, K., Bremer, P., Silcock, P., Hamid, N., Delahunty, C., Barker, M. and Kissick, J., **2009**. Effect of gender, diet and storage time on the physical properties and sensory of sea urchin (*Evechinus chloroticus*) gonads. *Aquaculture*, 288(3-4), 205-215.